CONSTRUCTION FOR COOLED SOLENOID

Field of the Invention

[00001] The present invention relates to electromagnetic solenoid coils, and in particular, cooling systems for such coils.

Background of the Invention

[00002] Electromagnetic solenoid coils self-heat due to resistive losses in their windings. This heating limits the endurance and power density capability of such coils. Cooling of these coils is normally provided by free convection and radiation to their surroundings. However, such convective and radiated cooling is a relatively slow heat transfer process at the normal operating temperatures for solenoid coils.

[00003] Consequently, there is a need in the art of electromagnetic solenoid coils for a non-passive cooling system to offset the resistive heating of solenoid coils. The present invention satisfies that need.

Summary of the Invention

[00004] An electromagnetic solenoid coil has an inner core through which a liquid or gas coolant flows. The coolant enters the inner core through an opening in the bottom of the core. The body of the inner core is in communication with a surrounding perforated bobbin. A pair of ordinary electromagnetic coil wires is wound around each other to form a helix, and the helix is then wrapped around the perforated bobbin. A

coolant flows into the inner core through the opening, and then to the duplex wound coil wires by way of the perforated bobbin. The duplex wound coil wires provide a connected porosity within the coil that permits the coolant to flow in a radial fashion through the coil from the coil's inside diameter to its outside diameter. In alternative embodiments, a supply manifold and a receiver manifold are integrated into the solenoid.

[00005] It is consequently an object of the present invention to provide an electromagnetic solenoid coil that can be cooled with liquid or gas coolant.

Brief Description of the Drawings

[00006] Figure 1 is an illustration of the liquid or gas cooled electromagnetic solenoid coil of the present invention.

[00007] Figure 2 is an illustration of a second embodiment of the liquid or gas cooled electromagnetic solenoid coil of the present invention fitted with supply and receiver manifolds.

[00008] Figure 3 is an illustration of a third embodiment of the liquid or gas cooled electromagnetic solenoid coil of the present invention fitted with a receiver manifold.

[00009] Figure 4 is an illustration of a duplex wound solenoid coil wire of the present invention.

[00010] Figure 5 is a block diagram of a cooling system for an electromagnetic solenoid coil.

Detailed Descripti n f the Inventi n

[00011] An electromagnetic solenoid 10 of the present invention is illustrated in Figure 1. The solenoid 10 has a simulated pole piece 35 that forms an inner core 15. The core 15 has opening 30 through which coolant enters the solenoid. Surrounding inner core 15 is perforated bobbin 20 and duplex wound solenoid coil wires 25. Coil wires 25 are shown in greater detail in Figure 4. Pole piece 35 and bobbin 20 are cross drilled so that the resulting ports 27 and 28 provide a radial means of communication from the inside diameter of the coil to the outside diameter of the coil. Ports 27 and 28 allow simulated pole piece 35 to communicate with the perforated bobbin 20. Perforated bobbin 20 in turn communicates with the duplex wound solenoid coil 25.

[00012] An alternative construction places a supply manifold 65 on the solenoid 10 as illustrated in Figure 2. Supply manifold 65 is in communication with plenum 66 which in turn connects with the inner core 15. Figure 2 further illustrates a receiver manifold 67 that is positioned on the solenoid 10. Plenum 68 is formed between the receiver manifold 67 and the solenoid coil wires 25. Another alternative construction uses the receiver manifold 67 without the supply manifold. This embodiment is shown in Figure 3.

[00013] Figure 4 illustrates in more detail wire 25 which makes up the coil. In a preferred embodiment, wire 25 is duplex wound, which provides connected porosity throughout the thickness of the coil. That is, the air space formed by the duplex wound coil wire connects the inner diameter of the coil with the outer diameter of the coil. In

alternative embodiments, three or more wires may be wound around each other to form the coil wire. In these alternative embodiments, the shape of the perimeter of the wound wires approaches a circle as more and more wires are wound. That is, three wires wound around each other approximate a triangle, four wires wound around each other approximate a square, five wires approximate a pentagon, and so on. As the outside perimeter of the wound coil wire approaches a circle, more and more wire is replacing the dead air space provided by wires wound of lesser numbers. Consequently a duplex wound wire provides the most dead air space, or porosity, and is the preferred construct.

[00014] The cooling system of solenoid 10 functions as follows. Coolant from a reservoir 50 is pumped by pump 55 through opening 30 into simulated pole piece 35. This flow is shown in flow diagram of Figure 5. Virtually any coolant fluid may be used as long as it is non-conductive and non-corrosive. Examples of suitable coolants include water, ethylene glycol, and hydrocarbon fuels and oils. Coolants that are in the gas phase may also be used including argon, nitrogen, carbon dioxide and air. While gases such as chlorine and fluorine could be used, they are less preferred because of the corrosive byproducts that they can form. An advantage of a gas coolant is that at the normal operation temperature of a solenoid coil there will not be a phase change as there might be with a liquid coolant.

[00015] After entering simulated pole piece 35, the pressure applied to the system by pump 55 causes the coolant to move through coolant feed ports 27 and 28, through the perforated bobbin 20, and then bathe the duplex wound solenoid coil 25. The porosity of

the coil winding provided by the duplex-twisted windings allows passage of large volumes of coolant. In particular, the porosity of the coil winding allows the coolant to travel radially from the inner core 15, through perforated bobbin 20, and to the outside diameter of the coil 25. The coolant limits the operating temperature rise of the coil wires 25 by removing heat from the warmer coil wires. Moreover, the through-coil coolant flows provide nearly independent control of input power and operating temperature which prevents coil overheat. After cascading over the wires 25, the coolant may be returned to reservoir 50. In an alternative embodiment, heat exchanger 60 cools the fluid on its way back to reservoir 50.

[00016] In the embodiment illustrated in Figure 2 with both the supply manifold 65 and the receiver manifold 67, coolant enters the supply manifold 65, flows through the plenum 66 and into the inner core 15. From the inner core 15, the coolant flows through the perforated bobbin 20, through ports 28, and then through the wound coil wires 25 in a radial fashion. After bathing the coil wires 25, the coolant exits the wound wires 25 and enters the plenum 68 and the receiver manifold 67. The path of the coolant is illustrated by arrow 69 in Figure 2.

[00017] In the embodiment illustrated in Figure 3, the coolant enters through opening 30, into inner core 15, through ports 27 and 28, and then into and through the coil wire 25 as previously described in connection with the embodiment illustrated in Figure 1. After exiting the coil wires 25, the coolant is collected in the plenum 68 and removed through the receiver manifold 67. For the embodiments with the supply

manifold 65 and the receiver manifold 68, the manifolds prevent coolant from escaping from the cooling system.

[00018] While the invention has been described in its preferred embodiment, it is to be understood that the words used are words of description rather than limitation and that changes may be made within the purview of the appended claims without departing from the true scope and spirit of the invention in its broader aspects.